Cryptozoology, 2, 1983, 85–89
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VERTICAL FLEXURE IN JURASSIC AND CRETACEOUS MARINE CROCODILIANS AND ITS RELEVANCE TO MODERN "SEA SERPENT" REPORTS

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ABSTRACT: Reports of "sea serpents" often mention that these animals move by vertical undulations of the body. It has been pointed out that, among living vertebrates, only mammals and birds can flex their body in a vertical plane, while fishes, amphibians, and reptiles can only undulate in a horizontal plane. However, the vertebral structure of Mesozoic marine crocodilians of the infraorder Thalattosuchia made vertical flexure possible. It thus appears that reports of vertical flexure do not necessarily demonstrate that the "hidden animal" in question cannot be a reptile.

A noteworthy feature of many "sea serpent" and "lake monster" reports is that the animal's body is said to undulate in a vertical plane. Almost a century ago, in his famous study of the "great sea serpent," A. C. Oudemans (1892: 523) stated that "generally it swims with vertical undulations." Modern popular imagination apparently also considers this type of locomotion as one of the most striking features of "sea serpents," to judge from the number of newspaper cartoons which show their bodies describing graceful loops above the surface of the water.

Bernard Heuvelmans (1965) devoted several pages of his exhaustive monograph on the "great sea serpent" to this question, and he mentioned this point again in his *Derniers Dragons d'Afrique* (1978), in connection with a "lake serpent" report from Lake Victoria. In both instances, he rightly pointed out that such vertical flexure of the body is of some importance in determining the zoological affinities of "hidden" aquatic creatures. In 1965, he remarked that all fishes, amphibians, and reptiles swim by horizontal undulations of the body, because the structure of their vertebrae does not allow flexure in a vertical plane (the amphisbaenians being the only exception among reptiles). Mammals and birds, on the other hand, are able to bend their vertebral column in a vertical plane, as exemplified by the movements in the water of aquatic mammals, which propel themselves largely by vertical undulations of the body. Heuvelmans also stressed the fact that the supposed vertical flexure in "sea serpents" is not merely a result of poor depiction of these animals by unskilful illustrators: innumerable witnesses concur in describing this particular mode of locomotion.

My aim here is to point out that, although Heuvelmans is correct as far as *living* reptiles are concerned, some extinct ones were, in fact, capable of vertical flexure. This has been shown by Bernard Krebs in a series of pa-

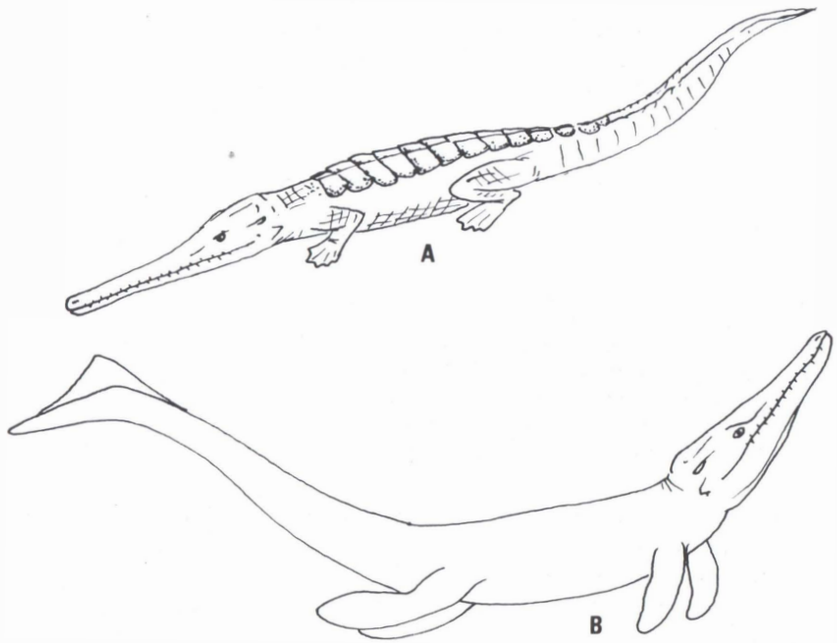

FIG. 1.—Reconstructions of two Jurassic thalattosuchians. A: the teleosaurid *Steneosaurus*. B: the metriorhynchid *Metriorhynchus*. Each animal could reach a length of about 4 meters.

leontological studies (1962, 1967a, 1967b, 1968) on Jurassic marine crocodilians belonging to two families of the archaic suborder Mesosuchia, the Teleosauridae and the Metriorhynchidae. These families of long-snouted crocodilians (Fig. 1), which lived during most of the Jurassic and disappeared in the early Cretaceous, were actually closely related, and can be included in a common infraorder, the Thalattosuchia (Buffetaut 1980, 1982).

Krebs based his inference on studies of the vertebral structure of these animals. The plane in which the body of an animal can bend is determined mainly by the orientation of the zygapophyses of its vertebrae. As pointed out by Alfred S. Romer (1956: 225), "a flat horizontal apposition of zygapophysial surfaces permits relatively free lateral movement within the column but sharply restricts vertical flexure; an increasing degree of tilt of the surface tends to restrict lateral bending but allows greater vertical movement." Krebs (1962: Fig. 3a) has very clearly illustrated the difference in the orientation of the zygapophysial facets between an animal which swims by horizontal flexure of the body, such as the alligator, and one which moves by vertical bending, such as a whale. While it is true that most known reptiles

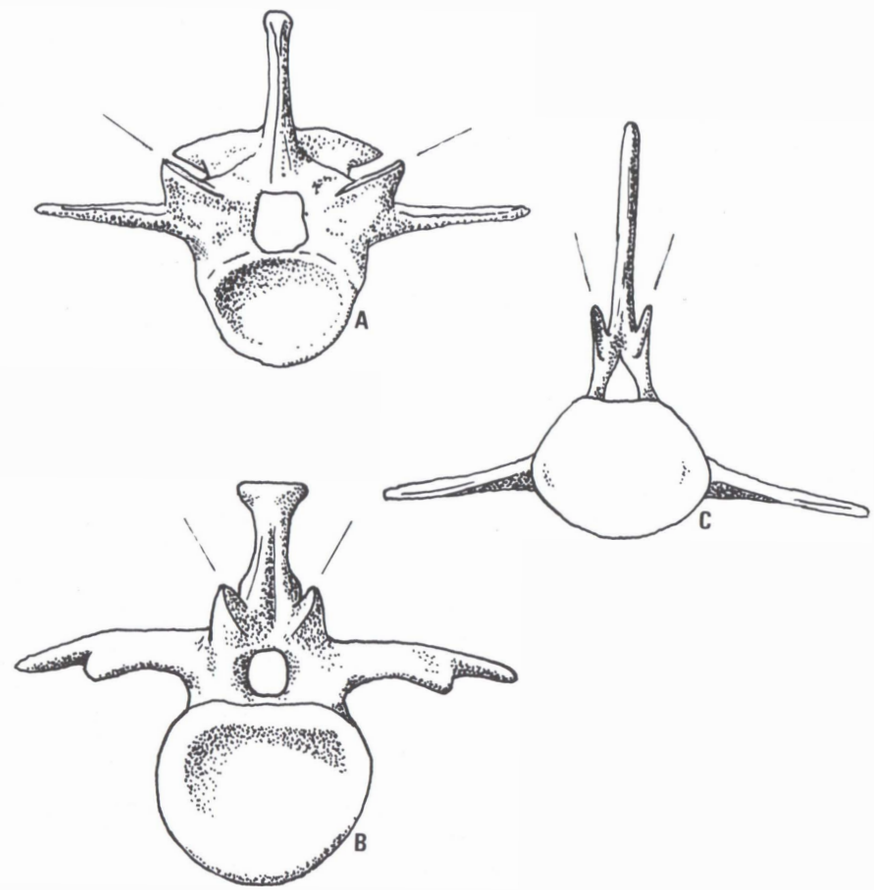

FIG. 2.—Anterior views of dorsal vertebrae of (A) the living alligator *Alligator mississippiensis*, (B) the Jurassic teleosaurid *Steneosaurus* sp., and (C) a living whale, *Balaena* sp. The straight lines indicate the tilting of the zygapophysial facets. The convergence between *Steneosaurus* and the whale in this respect should be noted; it indicates that vertical flexure of the body was possible in thalattosuchians. Redrawn after Krebs (1962).

are similar to the alligator in having zygapophysial facets in a subhorizontal or feebly tilted plane, Krebs showed that both the Teleosauridae and the Metriorhynchidae had strongly tilted zygapophysial facets, which are reminiscent of the condition exemplified by whales (Fig. 2), and which prevented lateral bending of the body while allowing vertical flexure.

According to Krebs (1962, 1967a, 1967b, 1968), the locomotor consequences of such a condition were that the Teleosauridae and the Metrio-

rhynchidae could not swim in the same fashion as modern crocodilians (which undulate in a horizontal plane), but were able to hold their body rigid while propulsion was effected by rapid movements of the end of the tail (which in metriorhynchids bore a small vertical fin). However, Krebs states that vertical flexure was also used, especially when these animals were diving.

Krebs' research on the vertebral structure and locomotion of thalattosuchians is obviously important to discussions of the zoological affinities of "sea serpents," because they show that, in some reptiles, a type of vertebra could evolve which permitted vertical flexure of the body while at the same time restricting horizontal bending. This does not imply that all (or any) reports of "sea serpents" undulating in a vertical plane are based on observations of surviving thalattosuchians. It is obvious that many features of most "sea serpent" reports are hardly compatible with the morphology of a crocodilian, which is rather different from that of a snake or an eel. Even such a specialized form as a thalattosuchian would be unable to bend its body in such a way as to produce the many vertical undulations mentioned in some eyewitness reports. Also, the thermic physiology of crocodilians, which restricts their range to the warmer parts of the world, is not compatible with the numerous sightings of "sea serpents" in cold waters. Nevertheless, Heuvelmans (1965), in his classification of "sea serpents," considers that a few reports of crocodile-like "sea monsters," from tropical areas, may be based on surviving thalattosuchians. In my opinion, this is by no means impossible; coelacanths were also supposed to be extinct since the Cretaceous until one was found alive in late 1938.

Whether or not some reports of "sea serpents" are based on crocodilians, the example of the Mesozoic Thalattosuchia shows that *some* reptiles have been able to acquire by convergent evolution a vertebral structure relatively similar to that of mammals, enabling them to bend their bodies in a vertical plane. This, in turn, shows that one should be cautious when using reports of vertical undulations as evidence for the mammalian nature of a "sea serpent." Vertical flexure may be a strong hint in favor of identification as a mammal, especially if it is accompanied by other corroborating evidence, but the possibility that it could be the result of convergent evolution in a non-mammal should also be kept in mind, all the more so that, in the Thalattosuchia, the evolution of strongly tilted zygapophyses is very likely to be the result of adaptation to a fully (or almost fully) aquatic life.

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